Innovative Installation Method for LPG Storage Tank Using TRIZ

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(Received 25 September 2012; final version received 28 January 2010)

Abstract

LPG (Liquefied Petroleum Gas) vehicles in metropolitan area are being applied to improve air quality and have been proven effective for the reduction of air pollutants. In addition, LPG demand is growing rapidly as an environmentally friendly energy source and its number of gas stations is also increasing every year. These gas stations are required to install the securest storage tank because of possibility of causing huge loss of life and properties. Therefore, in this paper, underground containment type is proposed as installation of the LPG storage tank using TRIZ, which is considered to be safer, economical, efficient, easy checking and simple construction method than any other.

Keywords: TRIZ, Installation Method, LPG, Storage Tank.

1. Introduction

Recently, the Korean government promotes green growth promises as a paradigm of national development which are to reduce greenhouse gases and environmental pollution by exhaust gases from automobiles. The automobile sector accounts for 19.3% of national energy consumption and has an ability to cut larger than other sectors, OECD (1996).

These fuel sources for vehicle's operating have been recently turned from gasoline to the gas to some extent. According to Korean Statistical Information Service, as shown in Table 1, the LPG quantity for transportation has increased 9.0% over the previous year. The demand for LPG bus station is increasing [AEGPL (1999)] causing air pollution problems. To solve the air pollution in urban areas, especially, LPG is projected as a relatively cost-effective alternative. According to Park (2009).

Changing in the gas fuel is a problem of the 'survival' beyond the 'quality of life' improvements, It rep- resents a new paradigm of 'sustainable development' which pursues economic development in harmony with environmental conservation.

When we use gas as fuel, it is effective in im- proving the environment by significantly reducing air pollutant emissions. It has a good efficiency in eco- nomic aspects because of a high-octane number. This is evidenced as domestic LPG gas station has increased three times during the last 10 years and the number of people completing training courses for safety manager about these facilities has grown rapidly.

Table 1. The state of LPG Consumption. (units: 1,000 ton).

Section	2004	2005	2006	2007	2008	Rate of increase(%)
Business	2,065	2,184	2,081	1,911	1,679	△5.4
City gas	75	96	69	62	178	2.8
Traffic	3,860	3,968	4,069	4,366	4,379	3.9
Industrial	481	509	504	637	650	4.2
Fuel	1,226	1,236	1,445	1,516	2,045	13.6

But, the studies of Lee and Lee (2003), CCPS (1994), Reid (1980), Kim et al. (2000), have shown that fire and explosion caused by leak incidents have occurred in large-scale facilities despite residing of safety manager. This is because LPG gas is difficult to detect due to its properties of colorless, odorless and formless. Especially, the representative examples of the accident in gas station occurred in Iksan gas station (UVCE: Unconfined Vapor Cloud Explosion) and Bucheon gas station (BLEVE: Boiling Liquid Expanding Vapor Explosion) resulting in many casualties and losses of enormous properties.

As the result of abovementioned two events in LPG station, Many researchers have inverted the related issues: Roh et al. (1999), investigated damage effect from Boiling Liquid Expanding Vapor Explosion (BLEVE) of LPG charging facilities; Bae (1999), studied on the Quantitative Analysis in LPG Tank's Fire and Explosion; Leem and Huh (2010) quantitatively Analyzed and Estimated damages to Surround Building caused by Vapor Cloud Explosion in LPG Filling Station; Lee and Lee (1999), researched consequence analysis of the fire & explosion on the flammable liquid handing facilities and LPG stations.

Jo (1999) studied on the minimum safe separation distance from LPG filling station and Park et al. (1999), learned about risk assessment of LPG storage facilities.

Based on these studies, the installation of storage tanks type regulations are buried underground or ground type to prevent accidents pursuant to Article 1[facility and technical standards of liquefied petroleum gas business] of Liquefied Petroleum Gas Safety Management and Business Law Enforcement Regulations Article 8 (2007).

LPG storage tank status installed is shown in Figure 1. According to research results of Jin et al. (2001), the most important factors causing the accident were structural defect and external accident in LPG leakage at charging facilities.

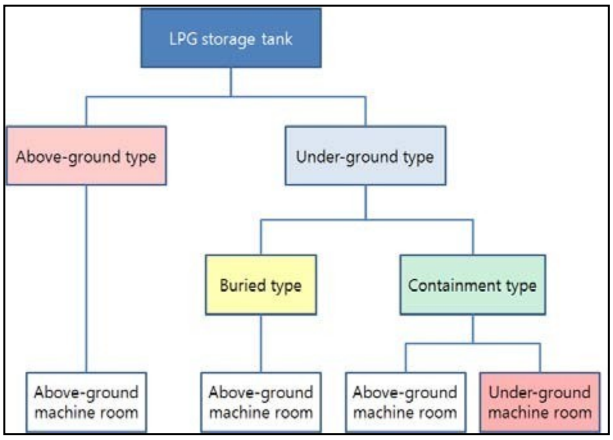


Figure 1. The State of the Installation for LPG Storage Tank.

To prevent this, he emphasized that the normal operation state through regular maintenance and repair works is important.

Therefore, Leem and Huh (2006) developed an intelligent decision system by safety distance of gas storage tank for safety managers in the field to prevent accidents complying with the related laws.

According to Korea Gas Safety Corporation, LPG storage tank status installed in charging facilities ap- plied by the current regulatory laws is shown in Table 2. It is noted that structural defects of storage tanks are actually difficult to check frequently because they are mostly installed as buried underground type.

Lee (2001) stated that the storage tank Installed on the ground has occurred BLEVE at temperature around 873K of its outer surface exposed to the fire.

Therefore, the storage tank installed above the ground pursuant could cause UVCE and BLEVE by a gas leak while buried underground type tank is extremely vulnerable to corrosion which degrades safety and economical efficiency.

Table 2. The State of LPG Filling Station. (Locating Type).

(units: ea)

Section	The storage tank(Locating type)			
	Above ground	Underground		Total
		Burial	Containment	
Total	173	1,703	110	1,986
Vessel	29	38	3	70
Vehicle	33	1,219	36	1,288
Vessel and Vehicle	70	420	70	560
Other	41	26	1	68

In this paper, construction method taken ad- vantage of practical TRIZ Step 6 of Kim (2006) and TRIZ techniques was proposed to reduce the danger and improve the economical efficiency of above-ground and buried underground types.

The existing containment type is similar to proposed style in this paper in the aspect of installing storage tank underground but transportation facilities as well as equipment parts of safety device are set up underground together. This is why the existing containment type has a high probability of gas leakage.

Containment shape proposed in this paper has a structure of only the storage tank is underground while moving all of the joints of equipment parts to above ground.

2. Theory

TRIZ is a Russian acronym for the Theory of Inventive Problem Solving, a problem-solving method based on technology rather than psychology. Genrich Altshuller, the TRIZ inventor, determined that the process of inventing could be significantly enhanced with a system that provides:

* A systematic step-by-step procedure
* Guidance to the area of the best solutions
* Reliable and repeatable results
* Access to the accumulated experience of innovation

According to Teplitskiy and Kourmev (2005), Royzen (2008), Domb (2000), Altshuller (1988), TRIZ grew to incorporate the knowledge abstracted from more than two million patents. As the TRIZ knowledge base grew, rigorous analysis revealed an objective, verifiable set of patterns and regularities related to the evolution of technological systems.

TRIZ helps us improve systems toward ideal design and it is useful for anyone to solve the problem easily and creatively.

Practical TRIZ 6 steps were applied to creativity one by one through the steps such as those in Figure 2. (6SC steps) 1) graphic representation, 2) the system's functional analysis, 3) ideal final result, 4) contradiction and the principle of separation, 5) element - inter- action, 6) evaluation and solutions and you can explore more creative solutions by looking at other methods for each principle.

3. Application of 6SC and evaluation

It is analyzed step by issue by applying 6SC to look for the solution of problems of above ground and buried underground type of LPG storage tanks.

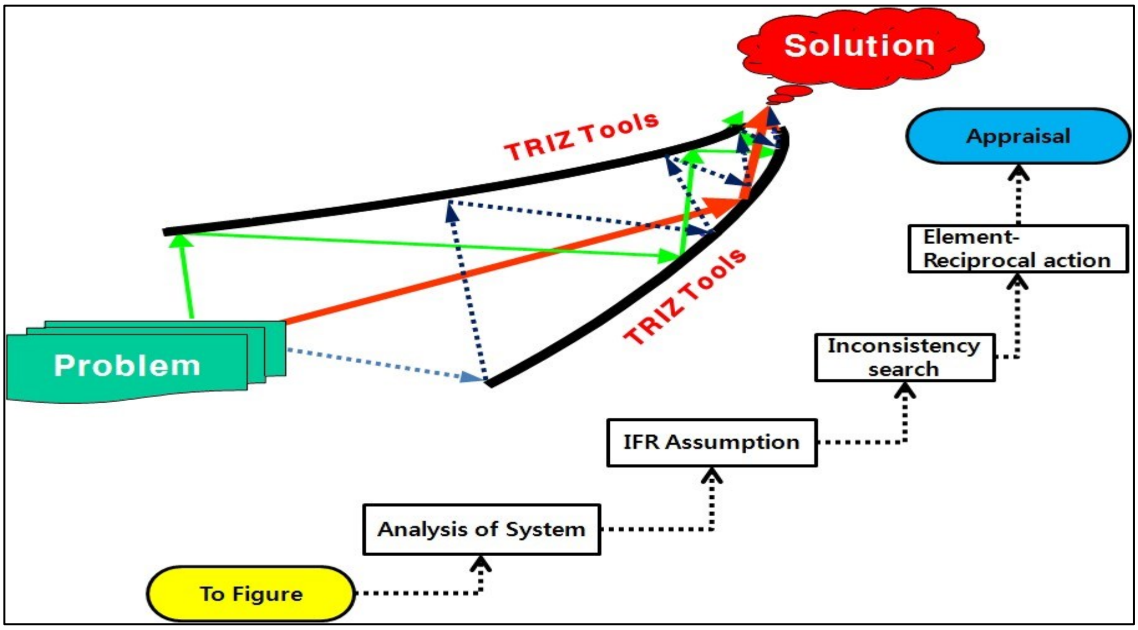
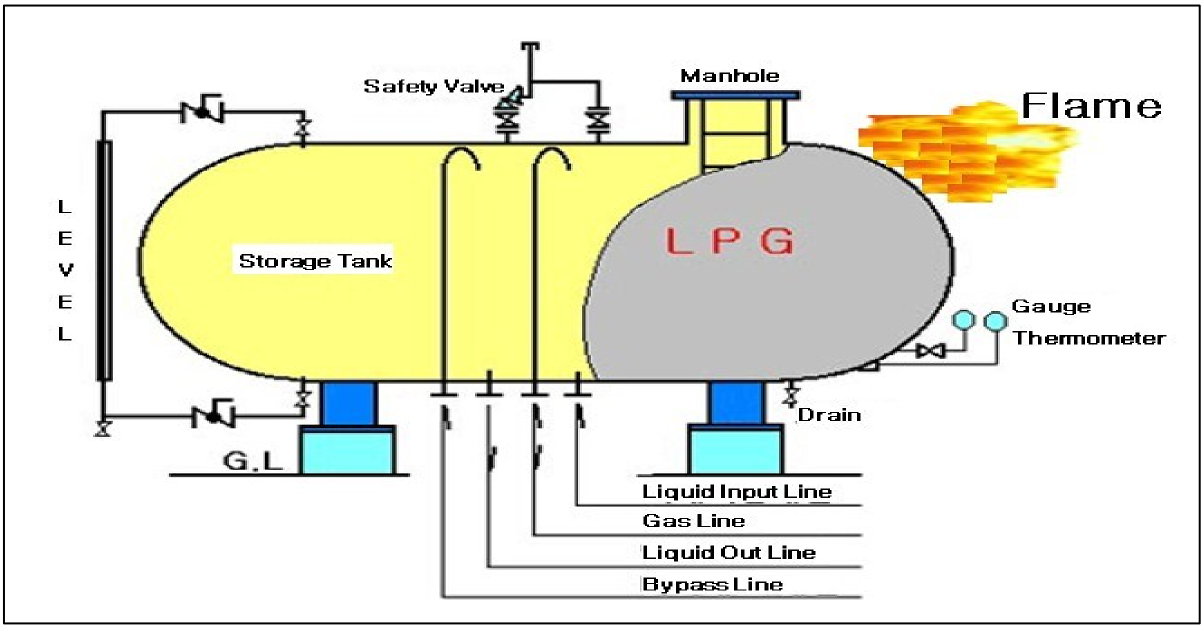


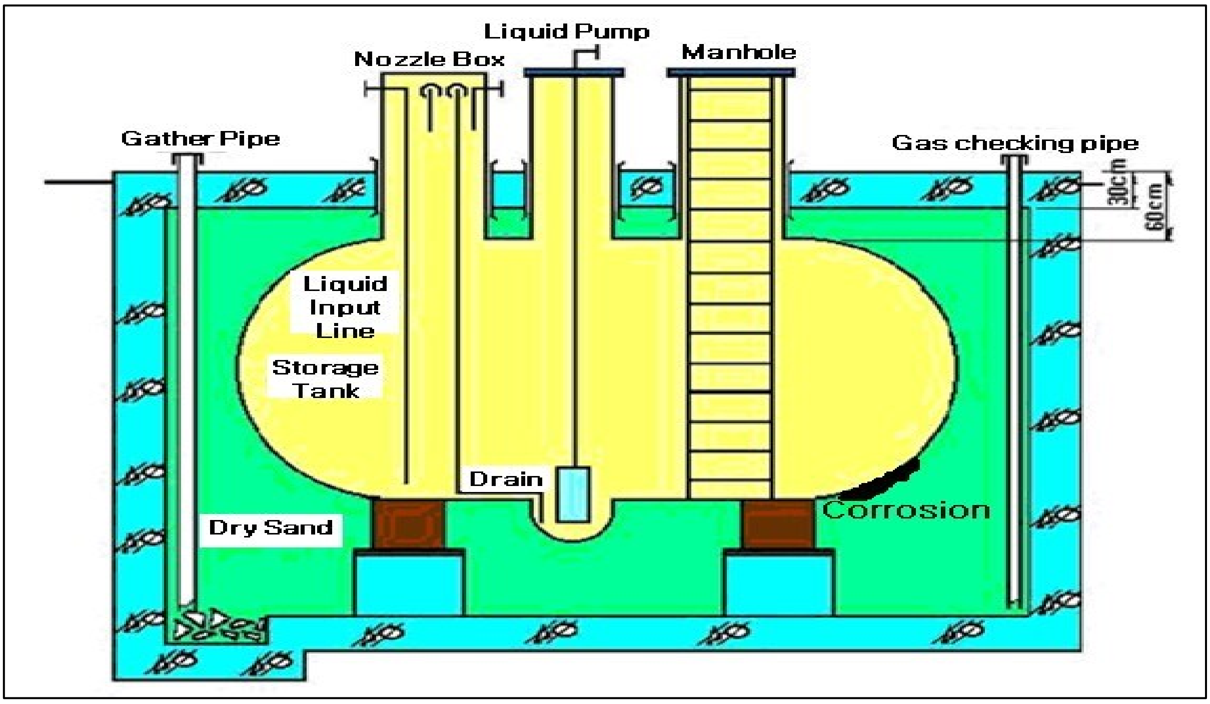
Figure 2. Application of 6SC Method.

3.1 Graphic representation

The best way to refine people's thought is to use pictures or diagrams. Graphic representation of the problem makes it easier to analyze situations and to determine the exact cause of the problem. They can be quickly and easily identified by representing the system as shown in Figure 3.



(a) Above ground type



(b) Underground buried type

Figure. 3. The Form of Existing Storage Tank.

3.2 Function analysis of the system

The functional analysis of the system is very importantly in the case when the technical challenges are not clear especially intertwined with its complexly. Especially, it is useful to represent schematically the contradictory relationship among parts or modules of complex systems.

Figure 4 is shown schematically problems and contradictions in the relationship of the above and buried underground type storage tank.

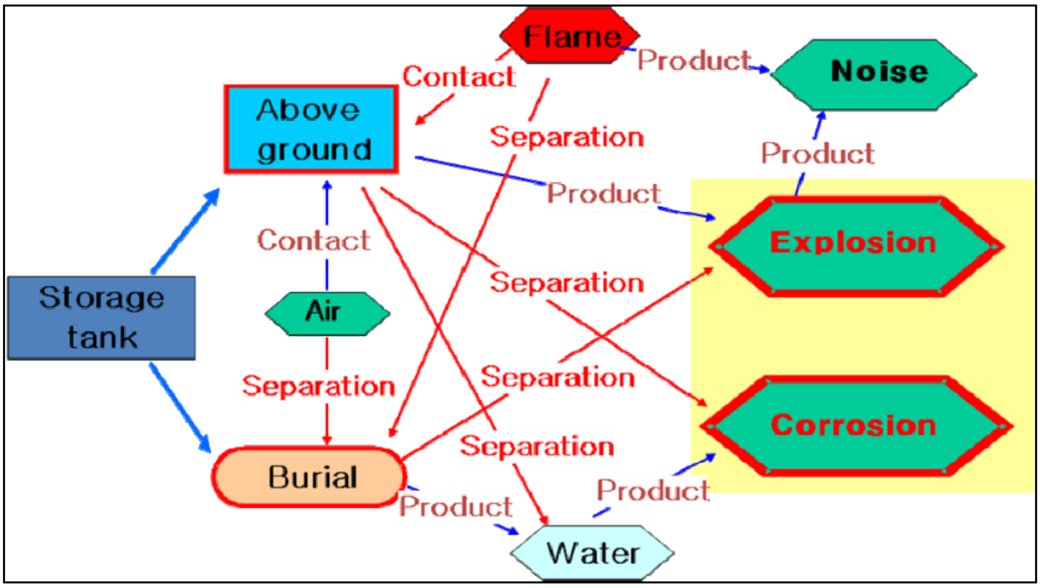


Figure 4. Composite Function Analysis of the System.

3.3 Ideal Final Result

The concept of the ideal final result is based on the law that Altshuller first formulated as follows: "The development of all systems proceeds in the direction of increasing the degree of idealness." This definition is start with the ideality equation (1).

$$Ideality = \frac{\sum Benefits}{\sum Costs + \sum Harm} \quad (1)$$

The formula generalizes numerous expressions presented to describe the level of technologies, inventions, and solutions. It was adapted from the value equation of Techniques of Value Analysis and Engineering in the early 1950s.

All systems have the ability to perform useful results and harmful effects at the same time. The Greek symbol Σ means "the sum of", so this equation reads, "ideality is the sum of all benefits divided by the sum of all costs and all harm." Useful features are that all the features you want in the system and harmful functions are the undesired results triggered from system cost, space, other pollution, and energy consumption.

IFR (Ideal Final Result) is a good methodology to escape from the stereotypes about problems and it is a system that does not exist while performing the required function.

3.4 Contradiction and the principle of separation

If you try to improve one attribute of the system, the other characteristics of the system deteriorate the situation. These contradict situation is one of the important concepts of TRIZ. it consists of two kinds; the technical contradiction and the physical contradiction. In this paper, the problem was resolved by solving 'physical conflict' having high utility.

LPG storage tanks must need to save the gas but it should not be for safety. The above ground type storage tank has dangerousness of an explosion caused by fire, so it should not be on the ground and the buried underground style should not be buried underground due to the economic loss by its corrosion. Therefore, storage tank should not be on the ground and buried underground.

3.5 Element-Interaction

Figure 5 is shown the element for interaction between above ground type and buried underground style. Element-interaction is a new methodology which can analyze in depth the problematic nature of each element. If you take advantage of this method, it is likely to find new technology separating from existing techniques.

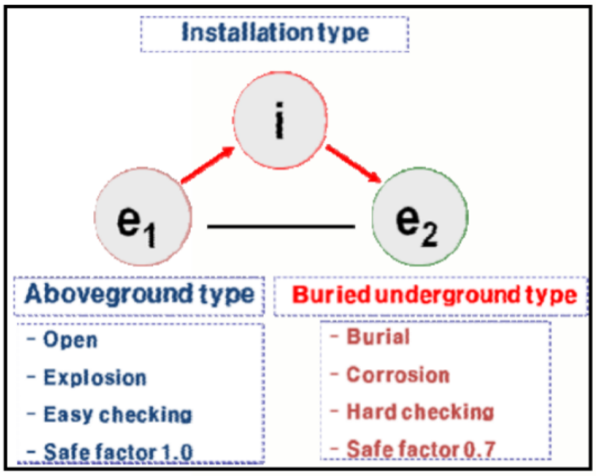


Figure 5. Elements-Interaction.

3.6 Evaluation and solution

Step 6 of 6SC is the final step to select and evaluate different solutions for the main problems.

Figure 6 shows the form optimized the issues of conflict and supplement of Figure 2. We can see in this graph that the problem of "the risk of exposing to fire" associated with above-ground type is ruled out and the problems of "economical issues from inspecting outer tank surface and the danger of corrosion and examination" associated with buried underground style is solved.

4. Conclusions

In this paper, the practical TRIZ 6 steps were implemented to solve the problems of LPG storage tanks. The problems of safety and economy are settled by using 6SC and the following effects are expected.

1. Underground containment type compared to the existing style is considered to shorten the construction period by improving the ability of working. Also the economic benefits will occur because it doesn't necessary to attach the sand.
2. Safety accidents could be prevented compared to conventional buried underground type thanks to the convenient operations.
3. It is expected to be more cost effective by reducing land area for charging facilities applied to the current legal regulations for the above-ground type.
4. It does not cause economic losses due to shell-type test cost of buried underground tank applied to legal regulations and it can rule out the risk of corrosion.
5. Containment type storage tanks contribute to vehicle filling business activation by social incongruity decrease of existing ground style storage tank.

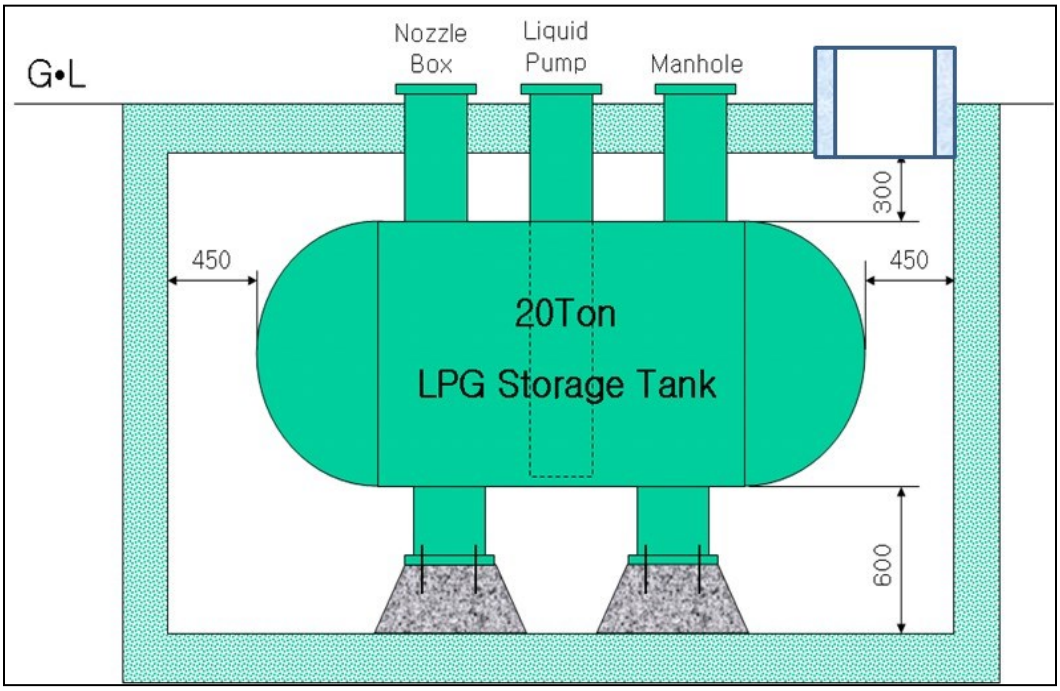


Figure 6. The Form of Improving Storage Tank.

References

Teplitskiy, A. and Kourmev, R. (2005). Application of 40 inventive principles in construction. *The TRIZ Journal*, USA.

AEGPL (1999). AEGPL Strategy Paper – LPG Heavy Duty Vehicles.

Altshuller, G. S. (1988). Creativity as an Exact Science, Gordon and Breach, New York.

CCPS. (1994). Guidelines for Evaluating the Characteristics of Vapor Cloud Explosion, Flash Fire and BLEVE, AIChE, New York.

Domb, E. (2000). *The Role of TRIZ in Six Sigma Management*, presented at TRIZCON2000, The Altshuller Institute, Nashua, New Hampshire.

Kim, H. J. (2006). 6 Steps creativity, Kim's TRIZ, Dooyangsa.

Kim, I. T., Kim, I. W. and Song, H. O. (2000). A study on the overpressure estimation of BLEVE. *Journal of the Korean Institute of Gas*, 4(1), 69-76.

Korea Gas Safety Corporation. (2009). Technical Inspection & Advisory Service Division. High-pressure Gas Statistics.

Korea Gas Safety Corporation. (2007). Liquefied Petroleum Gas Safety Control and Business Law.

Park, M. S., Seo, J. M., Lee, J. W., Kim, K. S., Kim, S. B., Ko, J. W. and Shin, D. I. (1999). A study for risk assessment of LPG storage facilities. *Journal of the Korean Institute of Gas*, 3(3), 9-16.

OECD. (1996). Integrating Environment and Economy, Progress in the 1990s.

Reid, R. C. (1980). Some Theories on Boiling Liquid Expanding Vapor Explosions, 525-526.

Royzen, Z. (2008). Designing and Manufacturing Better Products Faster using TRIZ. TRIZ Consulting, Inc., Seattle.

Leem, S. H. and Huh, Y. J. (2010). A study on the quantitative analysis and estimation for surround building caused by vapor cloud explosion (VCE) in LPG filling station. *Journal of the Korean Society of Safety*, 25(1), 44-49.

Leem, S. H. and Huh, Y. J. (2006). A development of intelligent decision system by safety distance of gas storage tank. *The Korea Academia-Industrial Cooperation Society*, 7(4), 721-726.

Roh, S. K., Kim, T. H. and Ham, E. G. (1999). A study on damage effect from Boiling Liquid Expanding Vapor Explosion (BLEVE) of LPG charging facility. *Journal of the Korean Institute of Gas*, 3(3), 45-50.

Jin, S. H., Kim, T. W., Kim, I. T., Kim, I. W. and Yeo, Y. K. (2001). A study on reliability analysis and quantitative risk analysis for liquefied petroleum gas station. *Journal of the Korean Institute of Gas*, 5(4), 40-48.

Lee, S. L. (2001). *A Study on the Probability of BLEVE of Aboveground LP Gas Storage Tanks Exposed to External Fire*. Seoul National University of Technology, Thesis for Master's Degree.

Lee, S. L. and Lee, Y. S. (2003). A study on the probability of BLEVE of above-ground LP gas storage tanks exposed to external fire. *Journal of the Korean Institute of Gas*, 7(1), 19-23.

Park, S. Y. (2009). German gas market trends – LPG gas increasing popularity of alternative fuels. *The Gas Safety Journal*, 35, 77-80.

Lee, S. K. and Lee, C. W. (1999). Consequence analysis of the fire & explosion on the flammable liquid handing facility and LPG station. *Journal of the Korean Institute of Gas*, 3(2), 77-84.

Bae, S. J. and Kim, B. J. (1999). The study on the quantitative analysis in LPG tank's fire and explosion. *Journal of the Korean Institute of Gas*, 3(1), 21-26.

Jo, Y. D. (1999). A study on the minimum safe separation distance from LPG filling station. *Journal of the Korean Institute of Gas*, 3(2), 24-33.

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